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Methods for Pore Water Extraction from Unsaturated Zone Tuff, Yucca Mountain, Nevada

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Abstract – *Assessing the performance of the proposed high-level radioactive waste repository at Yucca Mountain, Nevada, requires an understanding of the chemistry of the water that moves through the host rock. The uniaxial compression method used to extract pore water from samples of tuffaceous borehole core was successful only for nonwelded tuff. An ultracentrifugation method was adopted to extract pore water from samples of the densely welded tuff of the proposed repository horizon. Tests were performed using both methods to determine the efficiency of pore water extraction and the potential effects on pore water chemistry. Test results indicate that uniaxial compression is most efficient for extracting pore water from nonwelded tuff, while ultracentrifugation is more successful in extracting pore water from densely welded tuff. Pore water splits taken from a single nonwelded tuff core during uniaxial compression tests have shown changes in pore water chemistry with increasing pressure for calcium, chloride, sulfate, and nitrate, while the chemistry of pore water splits from welded and nonwelded tuffs using ultracentrifugation indicates that there is no significant fractionation of solutes.*

I. INTRODUCTION

The primary focus of the Yucca Mountain unsaturated zone (UZ) hydrochemistry investigation was to study the chemical and isotopic composition of pore water that resides in the UZ nonwelded and welded tuffs of Miocene age at Yucca Mountain, Nevada, site of the proposed repository for high-level radioactive waste (Fig. 1). Studying the hydrochemical processes in the UZ will provide a better understanding of the chemical composition of pore water that may contact the waste canisters.

Since 1990, the U.S. Geological Survey (USGS) has been developing methods for pore water extraction and analysis of micro-volume pore water samples. More than 300 analytical suites of unsaturated-zone pore-water chemistry data have been generated for the Yucca Mountain hydrochemical and isotopic investigations program. Initially, uniaxial compression was used to extract pore water from samples of tuffaceous core from surface-based

boreholes. However, this method of extracting pore water was successful only for core samples of nonwelded and partially welded tuffs *that overlie* (Paintbrush Tuff, PTn hydrogeologic unit, of Miocene age) and *underlie (*Calico Hills, CHn hydrogeologic unit, of Miocene age*), the proposed repository horizon.* Uniaxial compression proved to be ineffective for the densely welded tuff of the Topopah Spring (TSw hydrogeologic unit, of Miocene age), of the proposed repository horizon due to the tuff's high strength characteristics and low moisture content (Yang et al., 2003). In 1998 the USGS *adopted an* ultracentrifugation *method* to extract pore water from samples of TSw densely welded tuff.

The purpose of this paper is to discuss uniaxial compression and ultracentrifugation methods of pore water extraction developed by the USGS. The two methods are compared to determine the efficiency of pore water volume extracted verses the gravimetric moisture content of core samples. The results of pore water chemistry are used to determine the effects of the extraction methods on the original pore water composition. Pore water extraction tests described in this paper were performed on core samples from boreholes UE-25 UZ-16, USW SD-9, USW WT-24, and USW NRG-7A. The prefixes for the borehole names (UE-25 and USW) will be not be used in this paper.

II. METHODS

Accurate chemical analysis of samples of pore water extracted from borehole core samples of tuff depends on methods of borehole drilling, sample handling, and pore water extraction. The methods used to drill, handle, and store core samples are designed to prevent contamination and evaporation of pore water from the core samples. Pore water extraction methods have been developed and tested to determine the efficiency of extraction and the potential effects on the chemistry of the original pore water.

II.A. Borehole Drilling and Sample Handling

Surface-based and underground (in the Exploratory Studies Facility and the Enhanced Characterization of the Repository Block Cross Drift) boreholes were drilled using the vacuum-reverse-air-circulation drilling method described by Whitfield (1985). This method prevents the borehole core from being contaminated with drilling fluids, thereby allowing for the collection of pore water for hydrochemical analysis.

Core sample handling procedures were designed by the USGS and implemented by the U.S. Department of Energy (DOE), Yucca Mountain Sample Management Facility (SMF) to collect and preserve core for extracting

pore water. Precautions were taken to avoid evaporation or contamination of the core. Depending on the amount of core recovered from each core barrel and the degree of fragmentation, core samples were wrapped at the site in a multi-barrier package consisting of plastic wrap, Lexan® tube, and Protecore® (Striffler and Peters, 1993). Refrigeration of core samples between 4 and 9 degrees Celsius (°C) prevented evaporation and degradation of pore water by microbial activity.

II.B. Pore Water Extraction

Historically, pore water was extracted from samples of nonwelded tuff (PTn and CHn hydrogeologic units) by uniaxial compression (Mower et al., 1991; Higgins et al., 1997; Yang et al., 1996) and more recently from samples of welded tuff (TSw hydrogeologic unit) and nonwelded tuff (PTn and CHn hydrogeologic units) by ultracentrifugation (Yang et al., 2003). Typically, extracted pore water was filtered through 0.45 micrometer (μm) filters into polyethylene bottles and refrigerated between 4° and 9° C. If the volume of extracted pore water was sufficient, pH and specific conductance were measured immediately before storing the remainder of the sample for ion analysis.

Pore water samples extracted from borehole UZ-16 core were analyzed by Huffman Laboratories, Golden, Colo., between 1992 and 1998. The laboratory's relative error generally was less than ±10 percent for the analytes of standard reference samples (SRS) from the U.S. Geological Survey's analytical evaluation program for laboratories, except for alkalinity and silicon dioxide. Pore water samples extracted from borehole SD-9, WT-24, and NRG-7A cores were analyzed by the USGS Yucca Mountain Project Branch (YMPB) Hydrochemistry Laboratory, Denver Federal Center, Colo., with a relative error of less than ±10 percent for the SRS analyses, with the exception of fluoride, which had a relative error of ±15 percent.

II.B.1 Uniaxial Compression

The uniaxial compression cell can accommodate core samples up to 11 centimeters (cm) long and 6 cm in diameter, and weights up to 900 grams (g). Fragmented core and rubble also may be used for compression tests. The uniaxial compression test starts with progressive loading of the core sample to a stress level of 103 megapascals (MPa) at a rate of 69 kilopascals per second (kPa/s). Loading continues in eight increments of 103 MPa (at the same loading rate) until the final stress level of 824 MPa is reached. Pore gas is extracted almost immediately at the beginning of the compression test. As the pore spaces collapse and the core reaches 100 percent saturation, pore

water begins to migrate through Teflon® tubing (attached to drainage plates at the piston and base of the compression cell) and is collected in syringes. Once the maximum axial stress has been achieved and the core stops compacting, additional pore water can be collected by injecting dry nitrogen gas (99.99 percent pure) into the pore spaces (Yang et al., 1996).

Pore water extraction by uniaxial compression is most efficient for samples of nonwelded tuff with gravimetric moisture contents greater than 10 percent. For very wet, nonwelded samples (moisture contents greater than 20 percent), pore water yields can be as high as 80 milliliters (mL) from one compression test. Small amounts of pore water (less than 1.0 mL) may be extracted from samples of densely welded tuff with moisture contents greater than 6.5 percent using nitrogen injection. Samples of densely welded tuff from the TSw, however, generally have moisture contents less than 5 percent and do not yield pore water using compression methods.

II.B.2 Ultracentrifugation

In 1998 the USGS began developing methods for extracting pore water using centrifugation methods (Yang et al., 2003). This method extracts pore water by spinning tuff samples at a rate of 15,000 revolutions per minute (rpm) under thermostatically controlled conditions. The rotor spins inside a vacuum chamber, but Viton® A-O-rings maintain atmospheric pressure inside the buckets during the run. The centrifuge operation begins by loading approximately 150 to 250 g of core that has been broken into pieces 1 to 3 centimeters (cm) in diameter. A clean hammer, chisel, and rock-crushing bin are used for the sample preparation. Equal amounts of broken core are placed in the titanium centrifuge cups. A titanium plate with channels leading to a central porthole separates the rock from the extracted water in the attached polyethersulfone collection cup. Aluminum caps are screwed tightly to the titanium cups and the assemblies are placed inside three aluminum buckets. The buckets are attached to the rotor and the rotor assembly is placed into the centrifuge chamber. The entire process is performed in less than 10 minutes to minimize the evaporation of pore water. Samples are typically spun for a total of 4 to 6 hours at 15,000 rpm. After the centrifuge run, the extracted pore water is collected from the bottom collection cup in a clean plastic syringe and transferred into a plastic vial.

Ultracentrifugation methods are capable of extracting pore water from samples of densely welded tuff with moisture contents as low as 3 percent. Centrifuging samples of densely welded tuffs with moisture contents between 3 and 6 percent can yield 0.5 to 4.0 mL of pore water. Multiple runs of adjoining core intervals may be required to obtain enough volume for analysis (typically greater than 2.5 mL).

III. EXTRACTION METHOD TESTING

Several criteria were considered in selecting the best method for extracting sufficient volumes of pore water from Yucca Mountain tuff samples, including degree of welding and moisture content. However, the most important criteria are the effects that a pore water extraction method may have on the original chemical composition of the pore water.

III.A. Uniaxial Compression

Pore water extracted from nonwelded tuff by uniaxial compression tends to show changes in major ion chemistry with increasing pressure. Chemistry data for pore water extracted from two core samples with relatively high gravimetric moisture contents (M.C. %) of 18.5 and 19.1 percent show these chemical changes with increasing compression load. Each tuff sample yielded five pore water sample splits from different pressure ranges. The two tuff samples were from borehole UZ -16 core in the CHn hydrogeologic unit, about15 feet apart. Both samples were compressed within two days of each other and the pore water was analyzed on the same day. Sample splits are identified in Table I as UP-1 through UP-5. "UP" indicates "uniaxial pressed" at pressure ranges from 0 to 824 MPa. Residual pore water was measured by oven-drying the compressed core sample at 120°C for 48 hours. The pore water chemistry data are listed in Table II. To show relative changes in pore water chemistry with increasing load, the concentrations of the major ions have been normalized to the weighted average of solutes per volume of extracted pore water within each pressure range (Figs. 2a and 2b).

The results of these compression tests and those performed by Peters et al. (1992) indicate that chemical changes induced by greater compression loads appear to be relatively minor for pH, specific conductance, sodium (Na), bicarbonate (HCO_3), and silica (SiO_2), but more substantial for calcium (Ca), chloride (Cl), sulfate (SO_4), and nitrate (NO_3). In general, pH and SiO_2 concentrations increase with increasing pressure, while specific conductance and most major ion concentrations decrease with increasing pressure. Theses changes may be caused by the following factors: (1) Compression of clays and zeolites may result in dilution from the release of ion-deficient, ionically-bound water; (2) Formation of carbonic acid by the interaction of pore water and carbon dioxide gas contained in unsaturated pore spaces may cause changes in pH or alkalinity and dissolve minerals; (3) Ion exchange reactions with clays and zeolites may create changes in relative ion concentrations, such as an increase in Na relative to Ca, and $HCO_3$and SO_4relative to Cl; (4) Salts on the outer edges of the core samples from evaporation of pore

water during storage may be dissolved by the initial water removed during compression, resulting in decreased concentrations as additional water was extracted); and (5) Increasing concentrations of SiO_2 with increasing pressure could be caused by localized pressure solutions of silicate minerals during compression (Zell E. Peterman, U.S. Geological Survey, oral commun., 2003).

III.B. Ultracentrifugation

Pore water extracted from core samples by ultracentrifugation is subjected to very high centrifugal forces (up to 27,800 gravitational forces). Tests were conducted to determine how pore water chemistry is affected during extraction. Samples of densely welded TSw from borehole SD-9 were chosen to determine the efficiency of pore water extraction (volume of water extracted per gravimetric moisture content of core sample) using ultracentrifugation and the potential for chemical fractionation of pore water solutes. Because of the vertical variability of pore water composition in the TSw, tuff samples from two adjacent intervals (SD-9/669.7-669.8 and SD-9/669.8-669.9) with moisture contents of 5.4 and 6.2 percent, respectively, were used for this experiment to minimize this variability. The tuff samples were centrifuged for 4 to 6 hours at 15,000 rpm. The extracted pore water was collected and identified as sample "UC-1" (UC = ultracentrifuge), after which the collection cups were reattached and the tuff sample was centrifuged for another 18 to 20 hours at 15,000 rpm. The second pore water sample was collected and identified as "UC-2." The tuff sample was then removed from the centrifuge cups and oven-dried at 120°C for 48 hours to obtain the residual pore water (Table III).

The second split (UC-2) of pore water extracted from each of these tuff samples yielded only enough volume for the analysis of major anions (except bicarbonate) (Table II). A comparison of the anion chemistry of the two sample splits (with UC-2 being normalized to UC-1) is shown in Figure 3. With the exception of fluoride, the major anions of sample splits UC-1 and UC-2 were almost identical, indicating that no fractionation of solutes had occurred during pore water extraction from the two adjacent intervals.

A similar test was conducted on a sample of nonwelded core (CHn) from borehole WT-24 to determine the efficiency of pore water extraction by ultracentrifugation and the potential for fractionation of pore water solutes during extraction in the presence of clay and zeolite minerals. Tuff sample WT-24/2207.5-2207.7 had a moisture content of 19.5 percent. This sample was centrifuged for 1 hour at 15,000 rpm. A pore water volume of 5.0 mL was collected as the first split and was identified as "UC-1." The collection cups were reattached and the tuff sample was centrifuged for another 5 hours at 15,000 rpm. Upon completion of the second spin, 2.4 mL of pore water were

collected and identified as "UC-2." The tuff sample was then removed from the centrifuge cups and oven-dried at 120°C for 48 hours (Table IV).

The second split of pore water (UC-2) yielded enough water for analysis of all major ions as well as pH and specific conductance (Table II). A comparison of the chemistry of the two sample splits (with UC-2 normalized to UC-1) is shown in Figure 4. Major ions, pH and specific conductance of sample splits UC-1 and UC-2 were very similar, indicating that no fractionation of pore water solutes occurred during extraction from a nonwelded tuff.

III.C. Comparison of Extraction Methods

Yang et al. (2003) compared the chemistry of pore water extracted from core samples in general proximity of each other from boreholes SD-6 and WT-24 using compression methods and centrifugation methods. Pore water extraction and analysis dates varied from interval to interval. Their test results indicate that pore water samples extracted by these methods compare favorably within analytical error (13 percent) for most analytes. Two exceptions are pH and SiO_2, which tend to be higher in pore water extracted by uniaxial compression from samples of zeolitic nonwelded tuff (CHn).

For this investigation, a test was conducted to compare the chemistry of pore water extracted from adjacent core intervals of a nonwelded tuff (CHn) sample on the same day using uniaxial compression and ultracentrifugation methods. The extracted pore water also was analyzed at the same time. Compression of tuff sample NRG-7A/1504.3-1504.6 yielded 24.4 mL of pore water, which was collected as two split samples. UP-1 pore water collected between pressure ranges 0 to 412 MPa yielded a pore water volume of 12.6 mL. UP-2 pore water collected between pressure range 412 to 824 MPa yielded a pore water volume of 11.8 mL. Tuff sample NRG-7A/1504.2-1504.3 was centrifuged at the same time, yielding a pore water volume of 1.3 mL, labeled as UC-1. The chemistry of the pore water samples (with UP-1 and UP-2 normalized to UC-1) is compared in Figure 5 and Table II. Pore water sample UP-1 compares favorably with sample UC-1 within the estimated analytical uncertainty of the methods, while the concentrations of most ions in the UP-2 pore water are slightly lower.

Uniaxial compression methods are most efficient for extraction of pore water from nonwelded tuffs (volume of water extracted per gravimetric moisture content of core). The compression cell can accommodate a larger amount of tuff than the centrifuge cups, thus yielding larger volumes of pore water. Another advantage of using uniaxial compression methods is the ability to collect pore gas for analysis by gas chromatography. The disadvantage of uniaxial compression is the inability to extract pore water from densely welded tuff as described above. Also, the

destructive nature of this extraction method may expose fresh mineral surfaces to migrating pore water potentially causing dissolution of solutes and liberating ionically bound water from compressed clays and zeolites at the higher pressure ranges.

IV. DISCUSSIONS AND CONCLUSIONS

Pore water extraction tests using uniaxial compression methods have routinely shown changes in chemistry with increasing pressure, particularly for Ca, Cl, SO_4, and NO_3. A film of salts left on the perimeter of an intact core sample by evaporation during handling and storage may contribute to higher concentrations of solutes in pore water extracted from the first pressure range as water migrates from the inner core and re-dissolves the salts. The most reasonable explanation for the lower specific conductance and concentrations of most solutes in pore water extracted from the higher pressure ranges is the release of dilute, ionically-bound water from clays and zeolites. The increasing concentrations of SiO_2 with increasing pressure could be caused by localized pressure solutions of silicate minerals during compression. The increase in pH of pore water from the higher pressure ranges may be due to the formation of carbonic acid by the interaction of pore water and carbon dioxide gas contained in unsaturated pore spaces, thereby decreasing the pH of the original pore water extracted from the lower pressure ranges.

Pore water extracted from the higher pressure ranges comes from the smaller pores within the tuff and may be influenced by the capillary action of clays and zeolites, while pore water extracted at the lower pressure ranges would come from the larger pores within the tuff and therefore best represent the mobile UZ water. Pore water samples collected from the intermediate pressure ranges should prevent the influence of re-dissolved, evaporative salts and the addition of ion-deficient water from clays and zeolites.

Recent tests performed after Yang et al. (2003) used ultracentrifuge methods to extract and chemically analyze pore water from adjacent core intervals within a proximate time period have indicated that there is no significant fractionation of solutes from pore water split samples collected in sequence from the same tuff sample. Pore water extracted from adjacent core intervals by uniaxial compression and ultracentrifugation methods compare favorably within the analytical error for most analytes.

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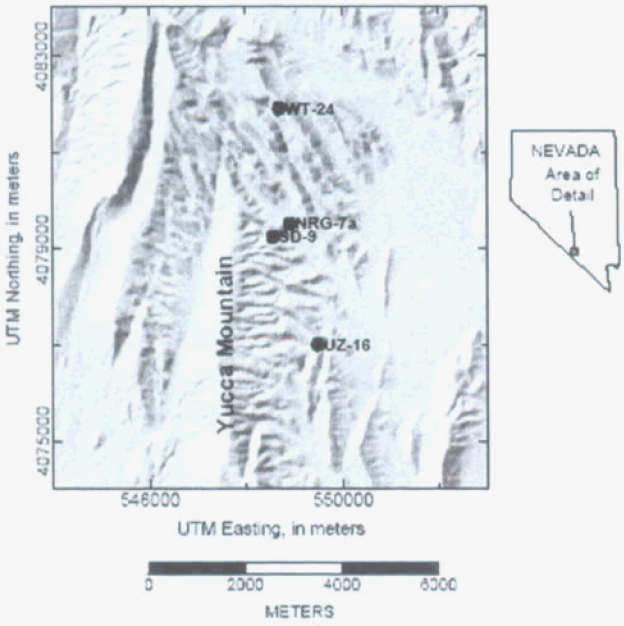

Fig. 1. Shaded relief map of Yucca Mountain, Nevada, showing borehole locations.

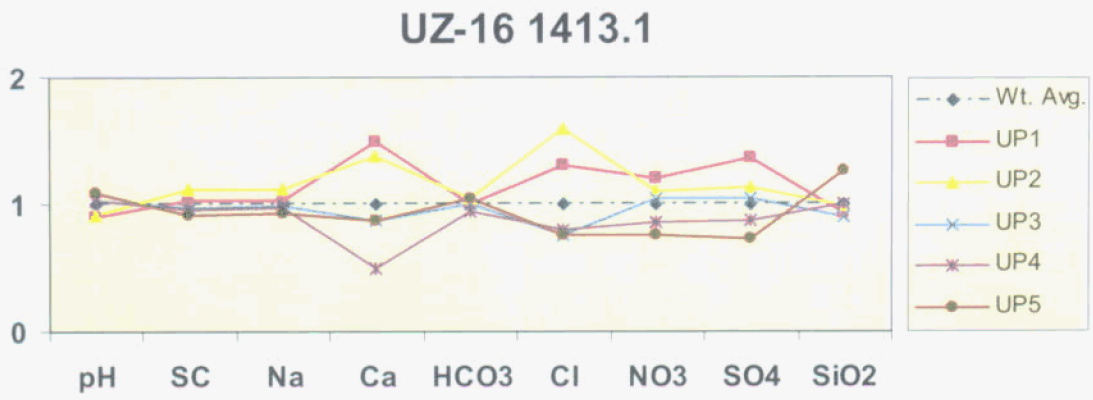

Fig. 2a: Pore water sample splits extracted from nonwelded core by compression. Changes in pore water chemistry with increasing load pressure have been normalized to the weighted average of solutes per volume of extracted pore water within each pressure range. UP = uniaxial pressed pore water splits from pressure ranges 1 to 5 (0 to 824 MPa).

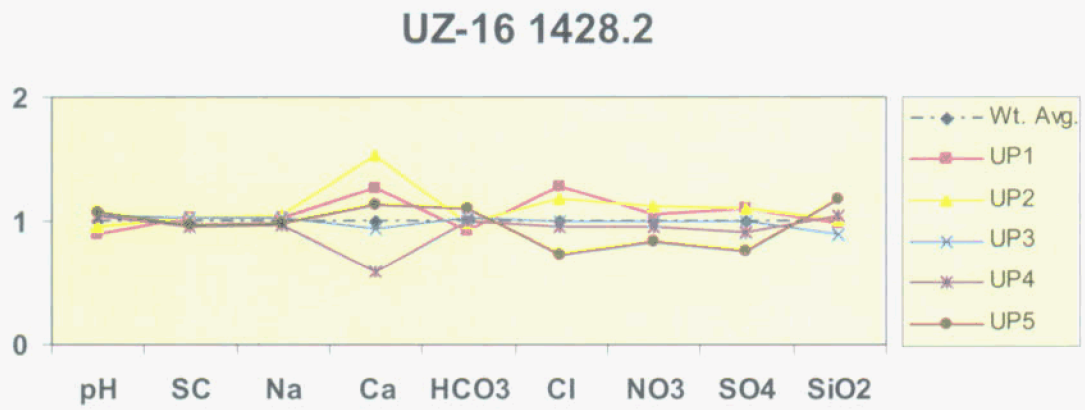

Fig. 2b. Pore water sample splits extracted from nonwelded core by compression. Changes in pore water chemistry with increasing load pressure have been normalized to the weighted average of solutes per volume of extracted pore water within each pressure range. U = uniaxial pressed pore water splits from pressure ranges 1 to 5 (0 to 824 MPa).

Fig. 3a. A comparison of the anion chemistry of two pore water sample splits extracted from a densely welded tuff by centrifugation, with UC-2 normalized to UC-1. UC-1 = ultracentrifuge, first sample split; UC-2 = ultracentrifuge, second sample split.

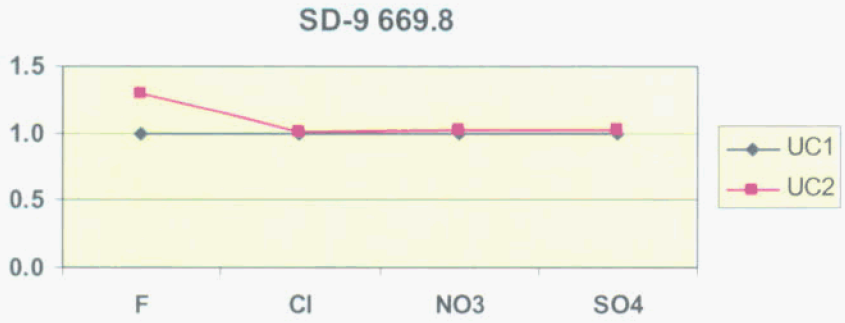

Fig. 3b. A comparison of the anion chemistry of the two pore water sample splits extracted from a densely welded tuff by centrifugation, with UC-2 normalized to UC-1. UC-1 = ultracentrifuge, first sample split; UC-2 = ultracentrifuge, second sample split.

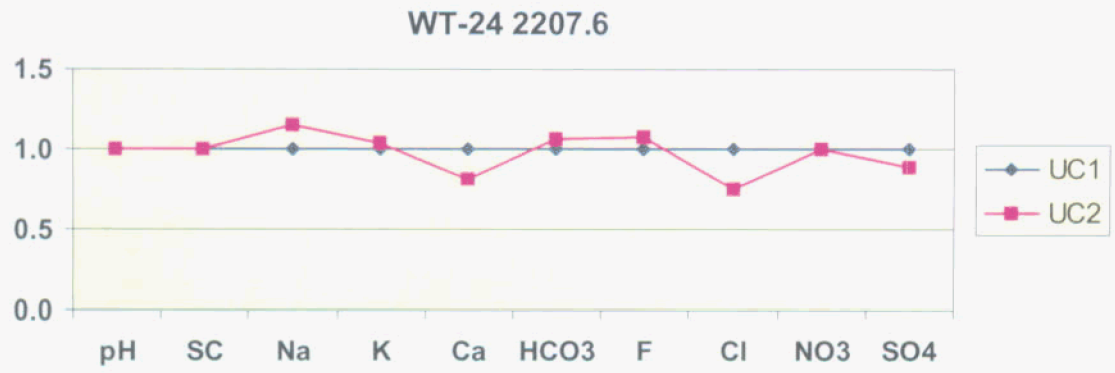

Fig. 4. A comparison of major ion chemistry of the two pore water sample splits extracted from a nonwelded tuff by centrifugation, with UC-2 normalized to UC-1. UC-1 = ultracentrifuge, first sample split; UC-2 = ultracentrifuge, second sample split.

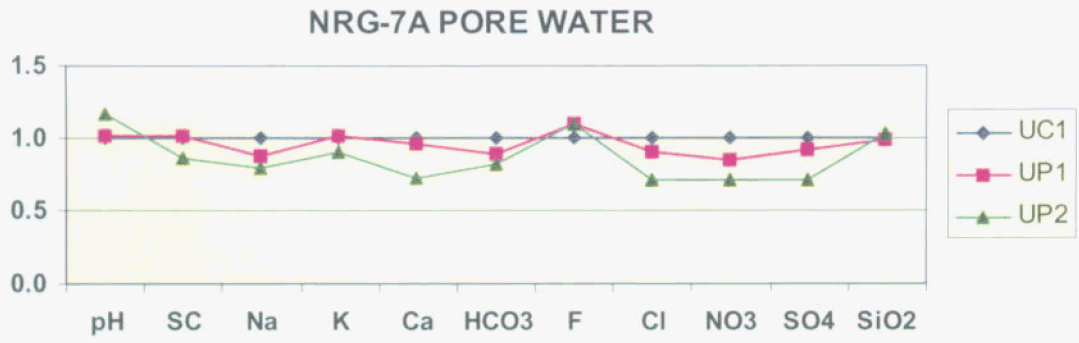

Fig. 5. A comparison of major ion chemistry of pore water extracted from adjacent, nonwelded core using uniaxial compression and ultracentrifuge methods. The chemistry of two pore water sample splits extracted by compression from lower and higher pressure ranges are normalized to the chemistry of the centrifuged pore water sample. UC-1 = ultracentrifuge sample split; UP-1 = compression sample split from the lower pressure range; UP-2 = compression sample split from the higher pressure range.

TABLE I. Uniaxial compression tests performed on two samples of nonwelded tuff from borehole UE-25 UZ-16, showing the volume of pore water extracted within each pressure range and the residual pore water left in the samples after compression

Sample ID	Wet Tuff (g)	M.C. %	Total Pore Water (mL)	Pressure Range (MPa)	Extracted Pore Water (mL)	% of total
UZ-16/1412.9-1413.2/UP-1	459.3	18.5	71.6	151 – 247	6.0	7.1
UZ-16/1412.9-1413.2/UP-2	NA	NA	NA	247 – 330	6.2	7.3
UZ-16/1412.9-1413.2/UP-3	NA	NA	NA	247 – 605	9.9	11.6
UZ-16/1412.9-1413.2/UP-4	NA	NA	NA	330 – 824	9.9	11.6
UZ-16/1412.9-1413.2/UP-5	NA	NA	NA	605 - 824	5.6	6.6
Residual pore water	NA	NA	NA	NA	34.0	47.5
UZ-16/1428.1-1428.4/UP-1	508.8	19.1	81.6	186 – 295	5.9	6.1
UZ-16/1428.1-1428.4/UP-2	NA	NA	NA	186 – 371	6.9	7.1
UZ-16/1428.1-1428.4/UP-3	NA	NA	NA	295 – 666	10.0	10.3
UZ-16/1428.1-1428.4/UP-4	NA	NA	NA	371 – 824	10.0	10.3
UZ-16/1428.1-1428.4/UP-5	NA	NA	NA	666 - 824	4.6	4.7
Residual pore water	NA	NA	NA	NA	44.2	54.2

UP: Uniaxial pressed pore water splits from pressure ranges 1 to 5 (0 to 824 MPa)

M.C.%: gravimetric moisture content

% of total: percentage of total pore water extracted

TABLE II. Pore water chemistry for pore water extraction tests

Sample ID	pH	S.C. µS/cm	Na	K	Ca	HCO_3	F	Cl	NO_3	SO_4	SiO_2	Charge Balance
UZ-16/1413.1/UP-1	7.8	450	101.0	na	1.2	165	na	26	24	30	75.9	0.1
UZ-16/1413.1/UP-2	7.9	490	110.0	na	1.1	171	na	32	22	25	80.7	2.8
UZ-16/1413.1/UP-3	8.9	430	96.8	na	0.7	166	na	15	21	23	72.7	3.5
UZ-16/1413.1/UP-4	9.0	420	95.0	na	0.4	155	na	16	17	19	81.5	6.3
UZ-16/1413.1/UP-5	9.5	400	90.6	na	0.7	172	na	15	15	16	103.0	2.0
Weighted Average	*8.7*	*440*	*98.2*	*na*	*0.8*	*165*	*na*	*20*	*20*	*22*	*81.4*	na
UZ-16/1428.2/UP-1	7.9	580	134.0	na	1.9	160	na	23	19	23	80.5	3.9
UZ-16/1428.2/UP-2	8.5	580	136.0	na	2.3	172	na	21	20	23	82.6	3.4
UZ-16/1428.2/UP-3	9.2	580	134.0	na	1.4	180	na	18	18	21	72.4	2.5
UZ-16/1428.2/UP-4	9.2	540	128.0	na	0.9	173	na	17	17	19	85.2	1.8
UZ-16/1428.2/UP-5	9.5	550	130.0	na	1.7	193	na	13	15	16	96.3	1.9
Weighted Average	*8.9*	*570*	*132*	*na*	*1.5*	*175*	*na*	*18*	*18*	*21*	*82*	na
SD-9/669.7/UC-1	na	na	na	na	na	na	7.5	47.3	21	44.6	na	na
SD-9/669.7/UC-2	na	na	na	na	na	na	6.3	44.2	20.6	45.6	na	na
SD-9/669.8/UC-1	na	na	na	na	na	na	4.8	43.8	20.5	42.2	na	na
SD-9/669.8/UC-2	na	na	na	na	na	na	6.2	44.2	20.9	43.3	na	na
WT-24/2207.6/UC-1	7.7	430	97.9	2.5	1.1	208	2.7	10.1	0.3	8.4	39.3	4.4
WT-24/2207.6/UC-2	7.7	460	112	2.6	0.9	220	2.9	7.6	0.3	7.5	na	9.0
NRG-7A/1504.2/UC-1	7.5	460	64	8.6	22	104	2.1	41	27	34	59	-0.16
NRG-7A/1504.3/UP-1	7.6	470	56	8.7	21	93	2.3	37	23	31	58	0.01
NRG-7A/1504.3/UP-2	8.8	400	51	7.8	16	85	2.3	29	19	24	61	1.23

TABLE III. Ultracentrifuge tests performed on sample splits of two samples of densely welded tuff from borehole USW SD-9, Yucca Mountain, Nevada, showing the volume and percentage of pore water extracted

Sample ID	Tuff (g)	Total Pore Water (g)	M.C. %	Run Time (hr)	Extracted Pore Water (mL)	% of Total
SD-9/669.7-669.8/UC-1	148.8	7.6	5.4	6	2.5	32.8
SD-9/669.7-669.8/UC-2	NA	NA	NA	18	0.6	7.9
Residual pore water	NA	NA	NA	NA	4.5	59.2
SD-9/669.8-669.9/UC-1	157.2	9.2	6.2	4	3.4	37.0
SD-9/669.8-669.9/UC-2	NA	NA	NA	20	0.8	8.7
Residual pore water	NA	NA	NA	NA	5.0	54.3

UC = ultracentrifuge sample splits 1 and 2

M.C.% = gravimetric moisture content

% of total = percentage of total pore water extracted

TABLE IV. Ultracentrifuge test performed on two splits of a sample of nonwelded tuff from borehole USW WT-24, showing the volume and percentage of pore water extracted

Sample ID	Tuff (g)	Total Pore Water (g)	M.C. %	Run Time (hr)	Extracted Pore Water (mL)	% of Total
WT-24 2207.5-2207.7/UC1	175.9	28.7	19.5	1	5.0	17.4
WT-24 2207.5-2207.7/UC2	NA	NA	NA	5	2.4	8.4
Residual pore water	NA	NA	NA	NA	21.3	74.2

UC = ultracentrifuge sample splits 1 and 2

M.C.% = gravimetric moisture content

% of total = percentage of total pore water extracted